Low Temperature Physics and Ultra-small Energy Physics Laboratory Group(Annual Report)

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Low Temperature Physics and Ultra-small Energy Physics Laboratory Group

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Research Activities

(I) ^{3}He-^{4}He Mixtures at Ultra-low Temperatures

(M. Morishita, T. Kuroda, A. Sawada and T. Satoh)

The search for the superfluidity of ^{3}He in ^{3}He-^{4}He mixtures is a big subject for the ultralow temperature physicists. In order to make a progress in this region, we should invent a way to cool down the mixtures below 100μK, at least. We are trying a new method in which we employ dilution refrigeration after pre-cooling liquid ^{3}He with a small amount of the mixtures below 400μK by nuclear refrigeration. In order to detect the superfluid transition, a vibrating wire viscometer and a NMR pick up coil are equipped in our experimental cell.

(II) Flow State of Superfluid Helium

(M. Okuyama, K. Torizuka, M. Suga, A. Sawada, H. Suzuki and T. Satoh)

(i) NMR study of the motion of ^{3}He in HeII

We have succeeded to explain the flow state of adiabatic flow of HeII up to very high velocity region of 100 cm/s by introducing a new-type mutual friction force between the superfluid and the normal fluid components. The analysis shows that there are several stages in the turbulent state of the quantum fluid HeII. We have employed the NMR technique to study the motion of

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^{3}He, which plays as a normal fluid component in HeII. It has been revealed that there are two characteristic velocities for the motion of ^{3}He. The meaning of these velocities and the relation with the turbulent states are very interesting future problem.

(ii) Superfluid phenomena of liquid ^{3}He

In order to investigate mainly flow state of superfluid ^{3}He, we are constructing a nuclear refrigerator. Dilution refrigerator with top loading mechanism will be completed soon.

(III) Dense Kondo System (N. Sato, N. Takeda, H. Suzuki and T. Satoh)

(i) Nonmagnetic-magnetic transition of the ferromagnetic dense Kondo system

In order to clearify the problem of moment formation and nonmagnetic-magnetic transition in the dense Kondo system, we have been studying the unique ferromagnetic dense Kondo system of Ce-Si based α-$ThSi_2$ structure. We have succeeded to make single crystals of these compounds.

From the analysis of the magnetic susceptibility data we have conjectured that the Γ_7-like doublet is the ground level of $CeSi_x$ system. The thermal expansion and the magnetostriction data support this ground doublet.

(ii) De Haas van Alphen effect of the dense Kondo system

The low temperature state of the dense Kondo system may be considered as a kind of Fermi liquid state in which 4f electrons are mobile via c-f mixing. In this respect, it is worthwhile to obtain direct information about the Fermi surface of the dense Kondo compounds. For this purpose we are trying to perform the de Hass van Alphen study in the temperature region around 10mK with magnetic field up to 80 kOe.

(IV) NMR Studies of Hyperfine Enhanced Nuclear Spin System in $Cs_2NaHoCl_6$
(Y. Masuda, H. Suzuki and T. Ohtsuka)

Hyperfine enhanced NMR of ^{165}Ho (I=7/2) in $Cs_2NaHoCl_6$ was measured above and below T_N=4.8mK. Observing the quadrupole splittings of the NMR spectrum the transition temperature of the crystal distortion from cubic symmetry was estimated as T_D=150mK. Antiferromagnetic resonance was measured below T_N following demagnetization cooling. The expected resonance frequency in zero field ω_0 for an uniaxial antiferromagnet was estimated as $\sim$278MH$_z$. The measurements were made at frequencies near ω^0 of 293MHz, 254MHz and 246MHz by CW NMR with a low field swept up to about 200e. From the observed resonance fields the zero field resonance frequency ω_0 was deduced to be 272MHz, not far from the expected frequency. This is the first observation of enhanced nuclear antiferromagnetic resonance.

(V) Kapitza Resistivity between $TmVO_4$ and Liquid ^3He and ^3He-^4He Dilute Mixture (N. Mizutani, H. Suzuki and T. Ohtsuka)

For the measurement of Kapitza resistivity between the hyperfine enhanced nuclear spin system $TmVO_4$ and pure liquid ^3He., the purifier of ^3He gas was constructed. The purified ^3He gas contained less than 5ppm ^4He. The pure liquid ^3He was cooled by demagnetization of CMN. The lowest temperature of the liquid was about 2.3mK. Measurements of Kapitza resistivity between $TmVO_4$ and pure ^3He below 10mK are in progress.

(VI) Fluctuation Effects in Aℓ/stearate/Aℓ Tunnel Junctions (K. Hatanaka, A. Sawada and T. Ohtsuka)

Electron tunneling between two aluminum films separated by one molecular layer of stearate film has been investigated. Zero bias tunneling conductance anomaly which we believe to be due to superconducting fluctuation effect, has been observed over a wide temperature interval from 1.9K to 9K. The functional dependence of excess tunneling conductance on temperature, bias voltage and magnetic field are in accordance with the theoretical predictions of the fluctuation tunneling between two normal metals.

Publications

1) N. Satoh, T. Satoh, T. Ohtsuka, N. Fukuzawa and N. Sato; ^4He-circulating Dilution Refrigerator, J. of Low Temp. Phys. 67 (1987) 195.
2) H. Yashima, Chui Feng Ling, T. Satoh, H. Hiroyoshi and K. Kohn; Fluctuation Effect at the Magnetic Transition of Ferromagnetic Dense Kondo System, Solid State Commun. 57 (1986) 793.
3) T. Takabatake, M. Ishikawa, T. Sakakibara, T. Goto and T. Satoh; Magnetic Heavy-electron Compound $CeCu_{1.54}Si_{1.46}$, J. of Mag. Mag. Mater. 63&64, (1987) 95.
4) M. Ishikawa, H. Yashima, M. Takahashi, T. Satoh and T. Takigawa; Effect of Composition on Several Physical Properties of $CeCu_2Si_2$, ibid., 351.

Doctor Theses

Toshimi Satoh: Adiabatic Flow of HeII.

Yumiko Masuda: Study of Nuclear Magnetism of Enhanced Nuclear Spin System Cs_2NaRCl_6 (R=Ho, Tm, Tb).

Nobuya Sato: Anisotropic Dense Kondo System $CeSi_x$.

Master Thesis

Shiro Sumita: Study of HeII Flow State by Measuring the Pressure Difference.